Breakup of *sd*-shell proton-rich nuclei for nuclear astrophysics

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At the end of 2004 the experiment E491 entitled "**^{23}Al proton breakup at intermediate energies and astrophysical consequences**" proposed by a group of scientists from our laboratory, IFIN-HH Bucharest, LPC Caen, France and a number of British universities was accepted by the PAC at GANIL Caen, France, and given maximum priority. In September-October 2006 we could run the experiment at GANIL. The initial motivation and the focus of the experiment was the determination of the spin and parity, of the ANC and of the configuration mixing in the ground state of ^{23}Al from the measurement of the momentum distribution of the core after the proton breakup on a light target. The method to use breakup reaction for nuclear astrophysics was proposed earlier by our group [1]. In order to do that, a special experimental setup was put together mostly by our collaborators at LPC. The Ge clover detectors of EXOGAM were arranged in a new configuration at the target position of the magnetic spectrograph SPEG. Also 12 NaI detectors were included in the system. The setup was meant for two experiments measuring coincidences between gamma-rays detected at the target position and the core remnants after breakup measured at the focal plane of SPEG. The two experiments were aimed at two different classes of nuclei: our experiment E491 was doing it for a number of radioactive proton-rich nuclei around ^{23}Al, the companion experiment E452 concentrated on neutron-rich nuclei around ^{23}O. They were the first experiments of this class to use high resolution Ge detectors for the detection of gamma-rays from the core excitations.

The primary beam from the GANIL cyclotrons was 95 MeV/u ^{32}S. A relatively stable current of 2 eμA was delivered on a 450 mg/cm^2 carbon target in SISSI. SISSI was tuned for a ^{23}Al secondary beam at magnetic rigidity Bρ=1.95 Tm. That gave about 15 kHz of secondary beam on the second target (C at 180 mg/cm^2) , made mostly of ^{24}Si, ^{23}Al, ^{22}Mg and ^{21}Na, with ^{23}Al @ 50 MeV/u being about 1.4% of total. With it on the C secondary target, we run at about 200 Hz of SPEG events and with each Ge and NaI detectors loaded at about 50, and 400 Hz, respectively.

With SPEG tuned at 1.75 Tm (later 1.76 Tm) we could see that we measure the momentum distributions for the cores of the beam nuclei after the removal of one proton: ^{23}Al, ^{22}Mg, ^{21}Na and ^{20}Ne. We have inclusive momentum distributions and in coincidence with gammas. We have good data collected in the 7 days of runtime.

One puzzle we had during the run, which appeared in the end to be good physics, rather than a problem. It turned out that in addition to ^{23}Al, ^{22}Mg, ^{21}Na, ... products, in the ΔE-bands we have their isobars ^{23}Mg, ^{22}Na, ^{21}Ne, ... (in pairs), and gamma-rays from each pair show in the gated Ge spectra. We found ways to clearly separate the two masses in each band and showed that they come from different mechanisms. In the conditions we ran, in the spectrometer, ΔE separates on mass (not Z). The ^{22}Mg component in the A=22 band, for example, comes from one-roton-removal from ^{23}Al, but the ^{22}Na component (and accompanying gammas) present at similar strength must appear from a charge-exchange reaction $^{12}C(^{22}Mg,^{22}Na)^{12}N$. Several states appear to be populated in each case. Bellow we see this separation, and we'll see what we can learn from here about the reaction mechanism and the structure of the states involved, it certainly looks interesting.

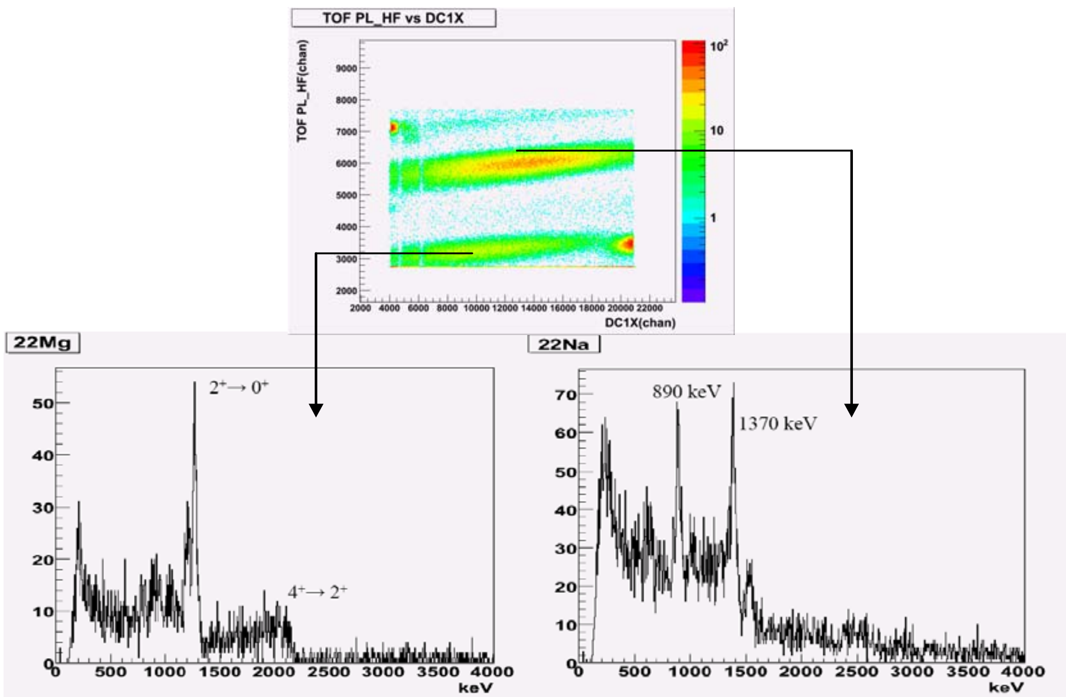

Figure 1. Illustration of the superposition of the two reaction mechanisms discussed in text. Top part shows for the same mass A=22 separated in the focal plane of SPEG split into ^{22}Mg and ^{22}Na. Bottom parts show the gamma-rays in coincidence with each one, separately.

The data analysis is still in progress. So far we have the data transposed from the GANIL format to a format that we can handle at TAMU, and we have the code for the analysis written from scratch, compiled and checked partially. In the same time we cooperate with colleagues from other teams to check the algorithms we use and the parameters we obtain, but also to minimize duplication of work.

[1] L. Trache, F. Carstoiu, C. A. Gagliardi, and R. E. Tribble, Phys. Rev. Lett. **87**, 271102 (2001).